Balloonborne Condensation Nuclei (CN) and Optical Particle Counter (OPC) measurements

Instrument: Condensation Nuclei (CN) counter and Optical Particle Counter (OPC)
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Instrument Description, OPC: The OPC is an *in situ* instrument which counts and sizes particles drawn into a sampling chamber. The instrument uses white light to measure aerosol scattering at 40° in the forward direction and Mie theory to determine aerosol size. Light scattered from particles passing through the beam is collected over a solid angle of ~ 30° and focused onto two photomultiplier tubes for pulse height detection. These instruments are sensitive to particles as small as 0.15 μm in radius. The upper channel is determined based on application, but typically varies between 2.0 μm for mid-latitude measurements and 10.0 μm for polar stratospheric cloud measurements. Twelve size classes are measured. The sample flow rate is 16.7 cm^3 s^{-1} and minimum detectable concentrations are 6 x 10^{-4} cm^{-3}. The instruments are designed for deployment on balloons and thus capable of providing vertical profiles of aerosol size distribution from the surface to 30 km.

Instrument Description, CN: A similar OPC with a flow rate of 1.67 cm^3 s^{-1} coupled with a chamber to supersaturate the sample air stream with ethylene glycol vapor is used to measure the total aerosol population, called condensation nuclei (CN). Particles > 0.01 μm in the sample stream grow to optical detection thresholds and are counted. The saturation chamber consists of a heated cylinder whose walls are coated with ethylene glycol. The condensing chamber, following the saturation region, is held at 0°C. The magnitude and duration of the supersaturation region in the condensing chamber is a function of pressure, decreasing from saturation ratios as large as 2 near the earth's surface to less than 1.5 above 50 millibars. The temperature of the saturation chamber is increased at low pressures to maintain adequate supersaturations.

Measurement products: The fundamental balloonborne measurements provide vertical profiles of size resolved aerosol concentration at 12 sizes plus CN. These measurements can be used to derive unimodal/bimodal lognormal size distributions to represent the measurements. A number of aerosol moments can then be calculated including aerosol extinction, volume, and surface area.

Calibration: Both aerosol counters are calibrated in the same way. Monodisperse aerosol particles are sampled and instrument gain is adjusted until measured instrument response is consistent with theoretical instrument response for the size and index of refraction of the particles used. Typically instruments are calibrated using commercially available polystyrene latex (PSL) spheres near 0.5 μm radius. This standard aerosol has been used since the 1970s. It is sufficient to calibrate the instrument using only one particle size. The theoretical counter response curve can then be checked using monodisperse particles of several sizes and refractive indices. This has been done a number of times.

Measurement Precision: Sizing errors result primarily from variations in photomultiplier response for a constant optical input. Variations in intensity of the light beam, and variations in aerosol paths through the beam, play a secondary role. Variation in photomultiplier tube response is a function of pulse height and decreases from 40% at the smallest sizes, 0.15 μm, to about 20% at 0.3 μm and larger. These errors lead to sizing errors which are a function of index of refraction but are primarily ~±10%, increasing to ±30% near 0.35 and 0.7 μm where the counter response curve is flatter. Errors in concentration depend on variations in air sample flow rate, the reproducibility of a measurement from two identical instruments, and Poisson counting statistics.. The pumps used for these instruments, constant volume gear displacement pumps, are quite stable and have been characterized in a pressure chamber. Laboratory tests with two identical counters indicate that the precision of concentration measurements is limited to ± 10% for relatively high concentrations of aerosol when Poisson counting statistics are not a factor. The Poisson error fraction, in terms of concentration, N, is $(N F / S)^{-0.5}$ for sample frequency, S = 0.1 Hz, and flow rate F. This error becomes important at low concentrations. In the stratosphere the Poisson uncertainties are 85, 25, and 8% for concentrations of 0.01, 0.1, and 1.0 cm^{-3} for CN and concentrations of 0.001, 0.01, 0.1 cm^{-3} for aerosol > 0.15 μm. This error dominates at concentrations below 0.1 (0.01) cm^{-3} for the CN (OPC). Monte Carlo tests using these size and concentration errors indicate that for lognormal size distributions fit to the *in situ* measurements, surface areas and volumes have uncertainties of ±40%, median radii ±30%, and distribution widths ±20%. These are the population standard deviations from the Monte Carlo simulations.

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